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Ito et al.

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(54) **METHOD AND APPARATUS FOR RECOGNIZING ACTIONS**

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G06K 9/00 (2006.01)
G06T 7/40 (2006.01)
G06K 9/46 (2006.01)

(52) **U.S. Cl.**

CPC ***G06K 9/00624*** (2013.01); ***G06K 9/00375*** (2013.01); ***G06K 9/4652*** (2013.01); ***G06T 7/408*** (2013.01)

(58) **Field of Classification Search**

CPC combination set(s) only.
See application file for complete search history.

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(57) **ABSTRACT**

An information processing apparatus obtains a picture containing an image of a person from an imaging device. Also obtained are first data indicating distance of the person and other subjects seen in the picture from the imaging device, second data indicating distance of a wrist of the person from the imaging device, and third data indicating a coordinate position of the wrist in the picture. The information processing apparatus extracts a set of pixels whose coordinates fall within a specified coordinate range defined around the coordinate position of the wrist and whose distances from the imaging device fall within a specified distance range defined around the distance of the wrist. Then based on a ratio representing how many of the extracted pixels have a distinctive color tone, the information processing apparatus determines whether the person has picked up an object.

15 Claims, 18 Drawing Sheets

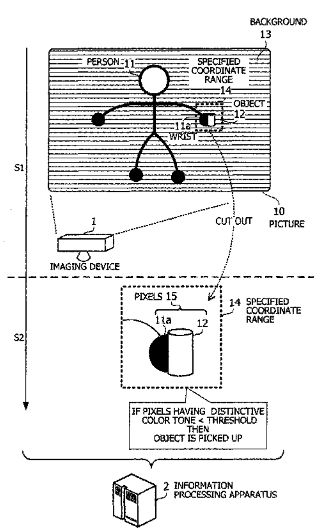


FIG. 1

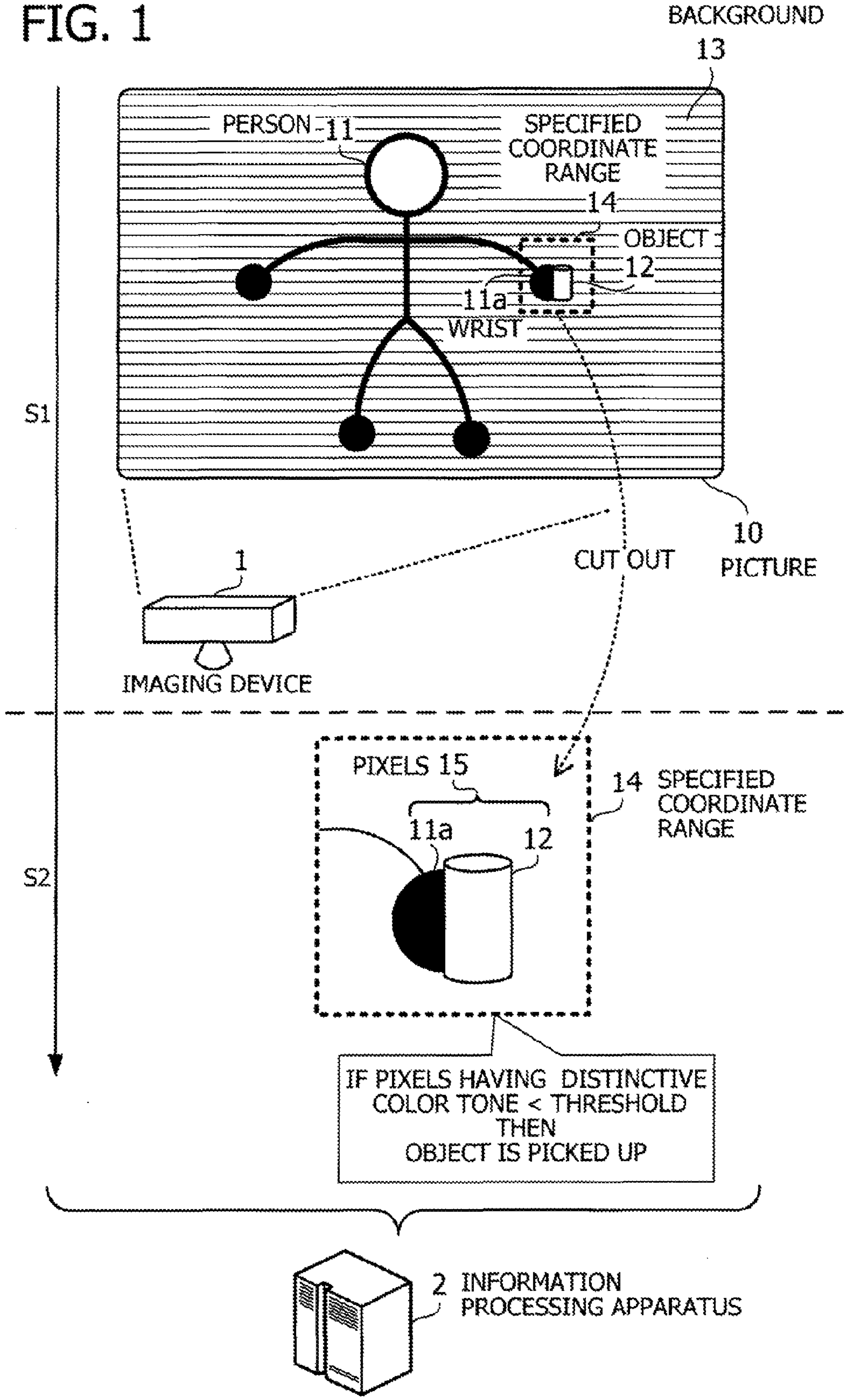

BACKGROUND
13
PERSON 11
SPECIFIED COORDINATE RANGE
14
OBJECT
12
11a
WRIST
S1
10
PICTURE
CUT OUT
1
IMAGING DEVICE
PIXELS 15
11a
12
14 SPECIFIED COORDINATE RANGE
S2
IF PIXELS HAVING DISTINCTIVE COLOR TONE < THRESHOLD THEN OBJECT IS PICKED UP
2 INFORMATION PROCESSING APPARATUS

FIG. 2

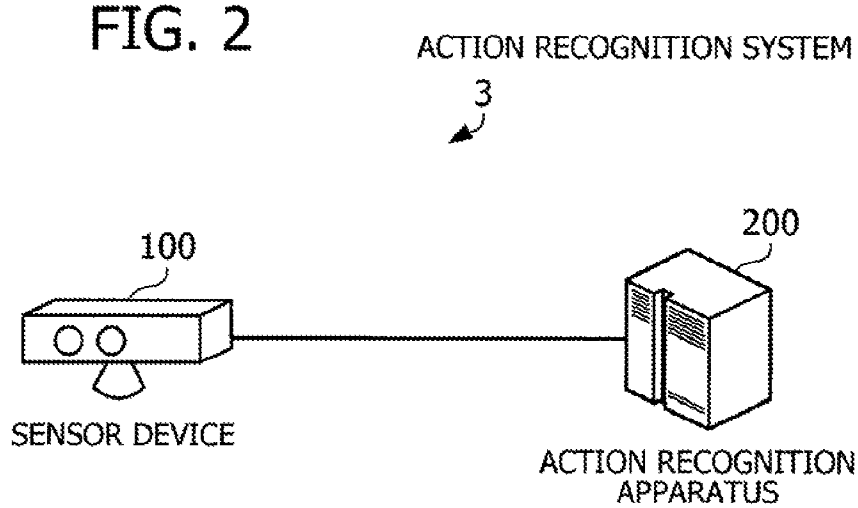

ACTION RECOGNITION SYSTEM
3
100
200
SENSOR DEVICE
ACTION RECOGNITION APPARATUS

FIG. 3

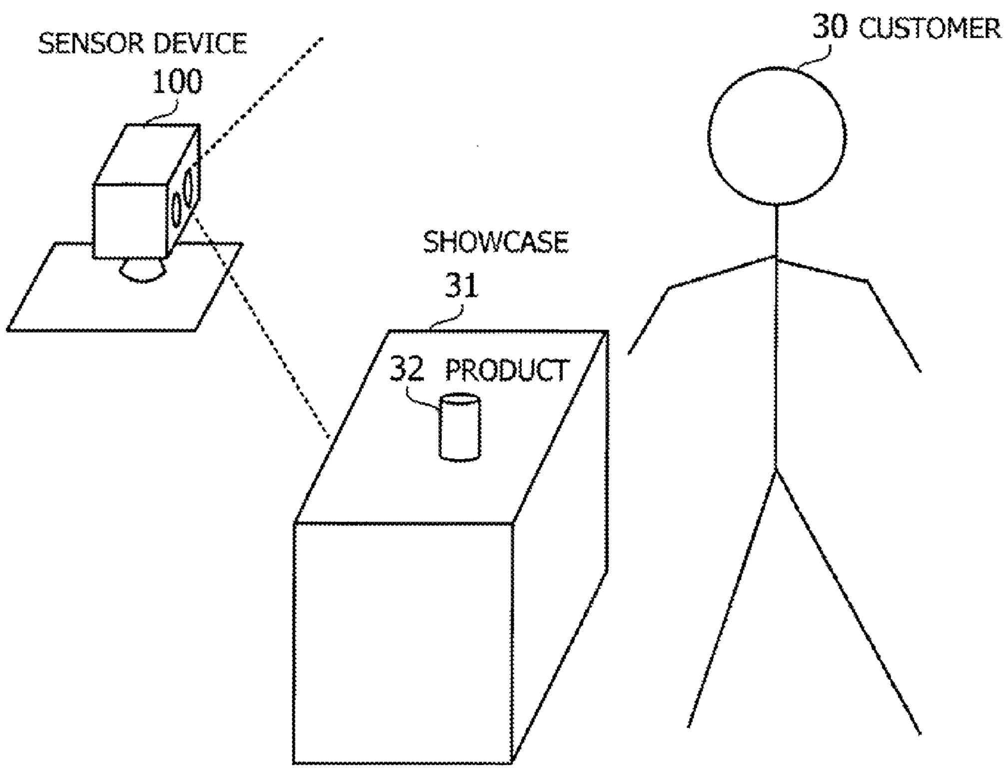


FIG. 4

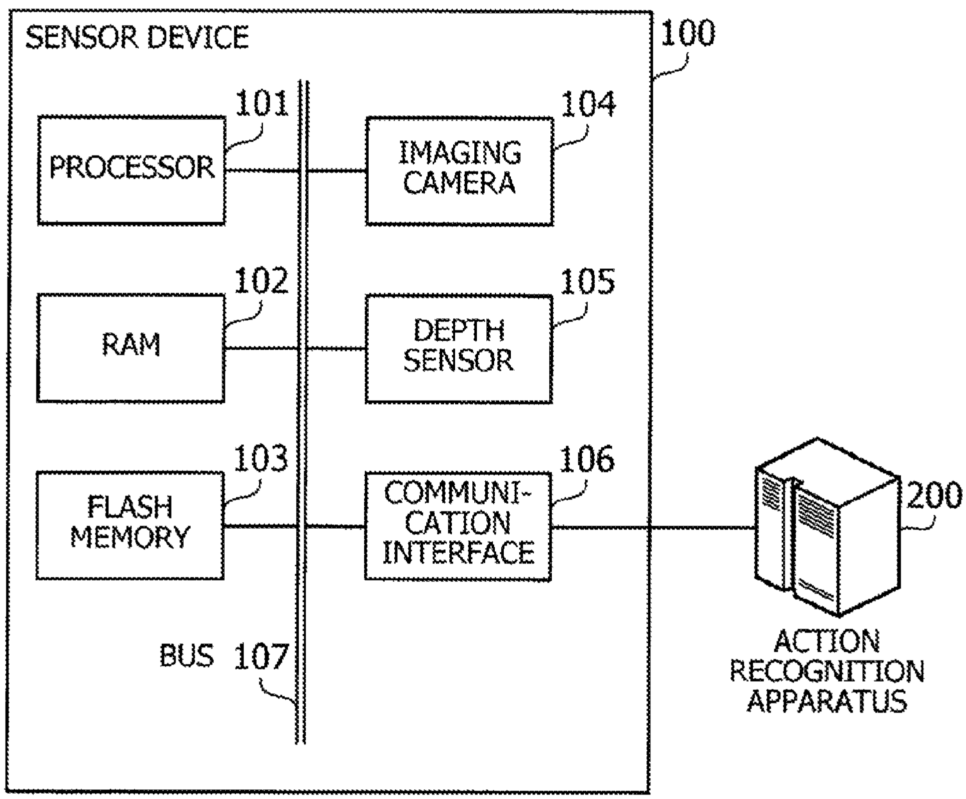

SENSOR DEVICE
100
101
PROCESSOR
102
RAM
103
FLASH MEMORY
104
IMAGING CAMERA
105
DEPTH SENSOR
106
COMMUNI-CATION INTERFACE
BUS 107
200
ACTION RECOGNITION APPARATUS

FIG. 5

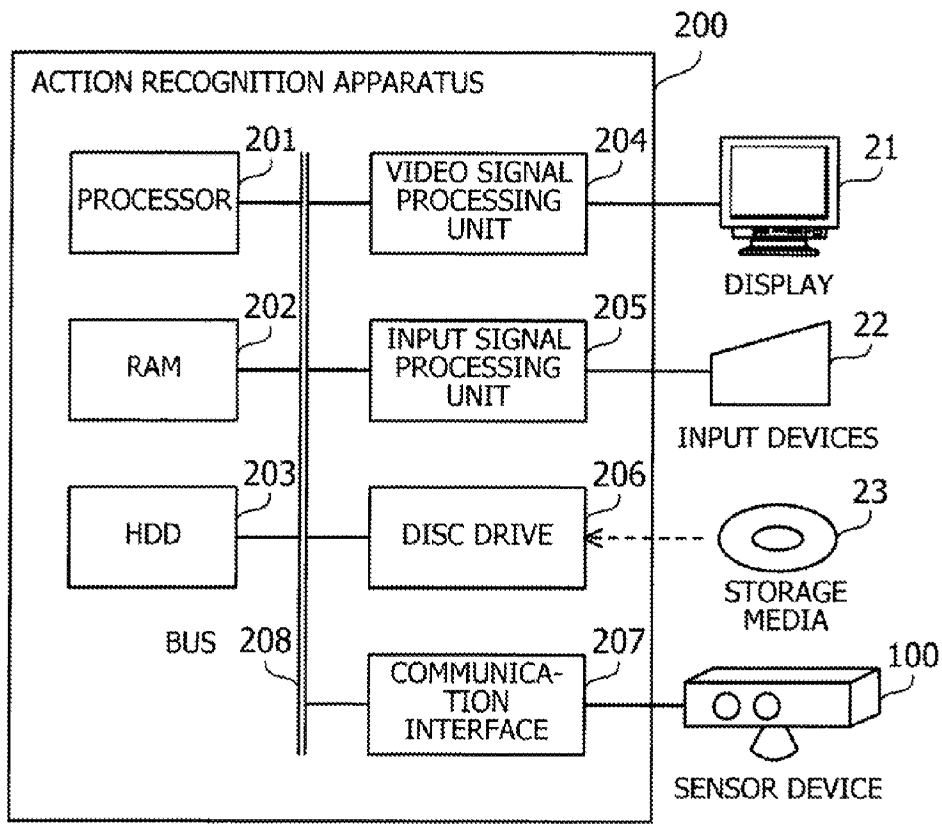

200
ACTION RECOGNITION APPARATUS
201
PROCESSOR
204
VIDEO SIGNAL PROCESSING UNIT
21
DISPLAY
202
RAM
205
INPUT SIGNAL PROCESSING UNIT
22
INPUT DEVICES
203
HDD
206
DISC DRIVE
23
STORAGE MEDIA
BUS 208
207
COMMUNICATION INTERFACE
100
SENSOR DEVICE

FIG. 6

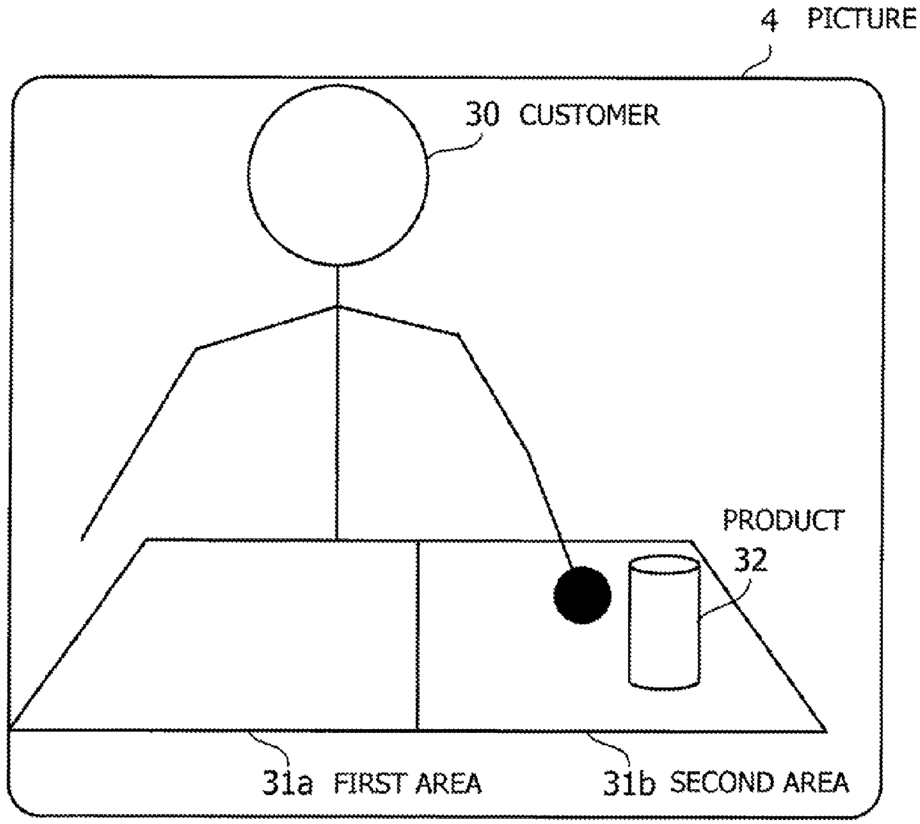

4 PICTURE
30 CUSTOMER
PRODUCT
32
31a FIRST AREA
31b SECOND AREA

FIG. 7

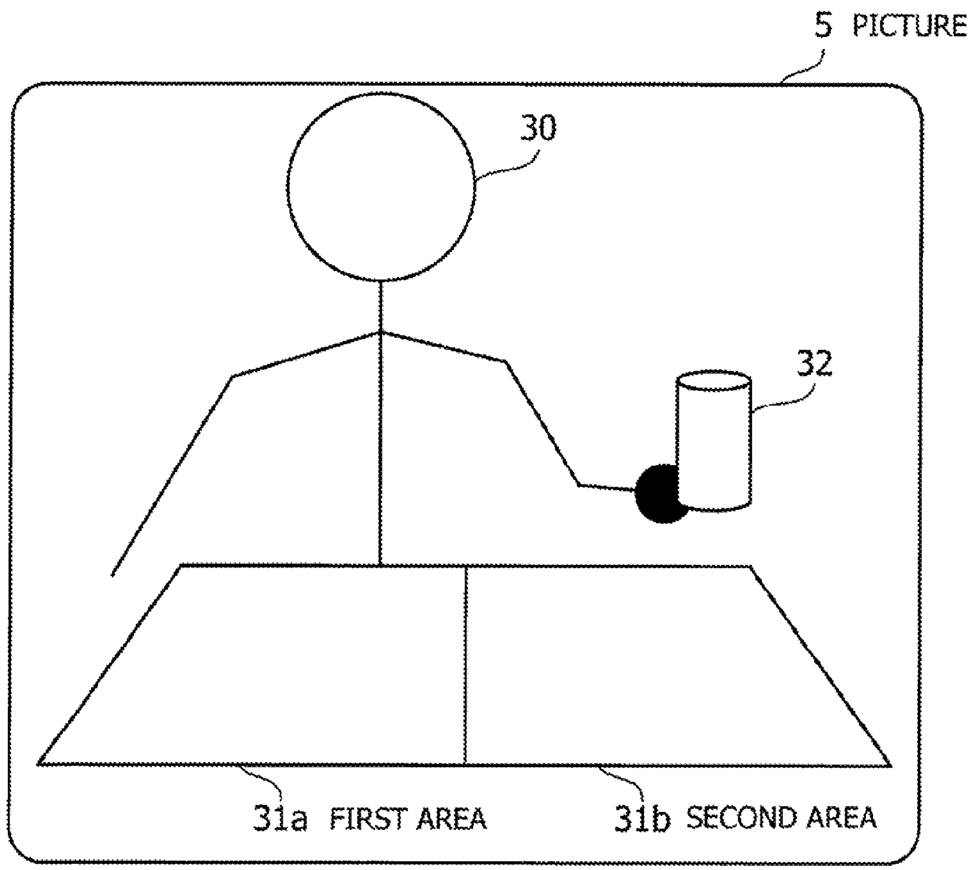


FIG. 8

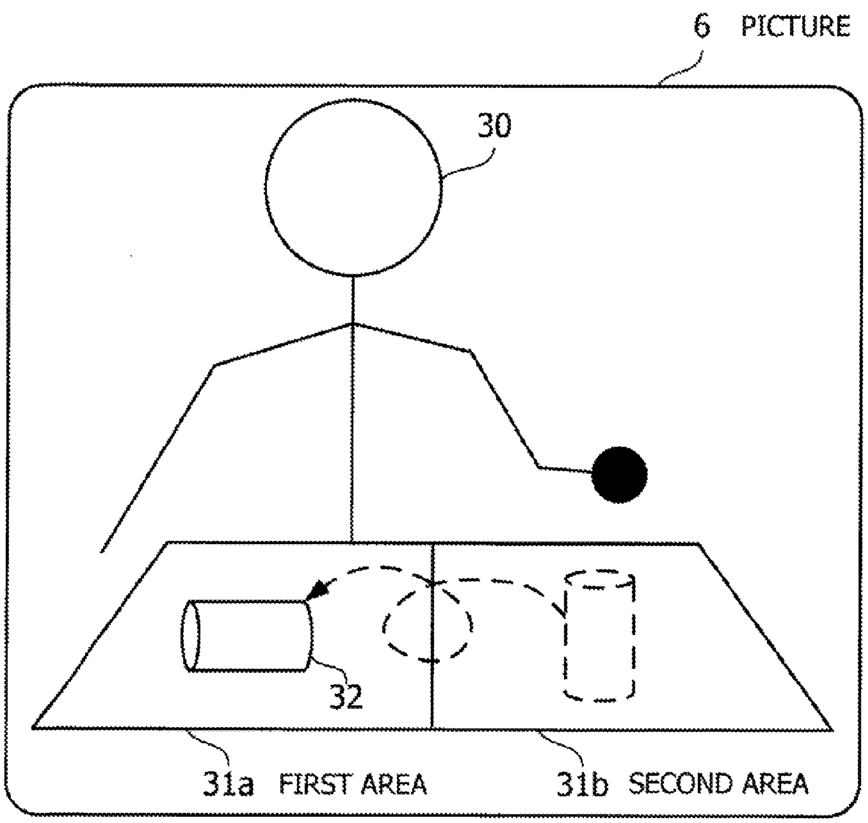


FIG. 9

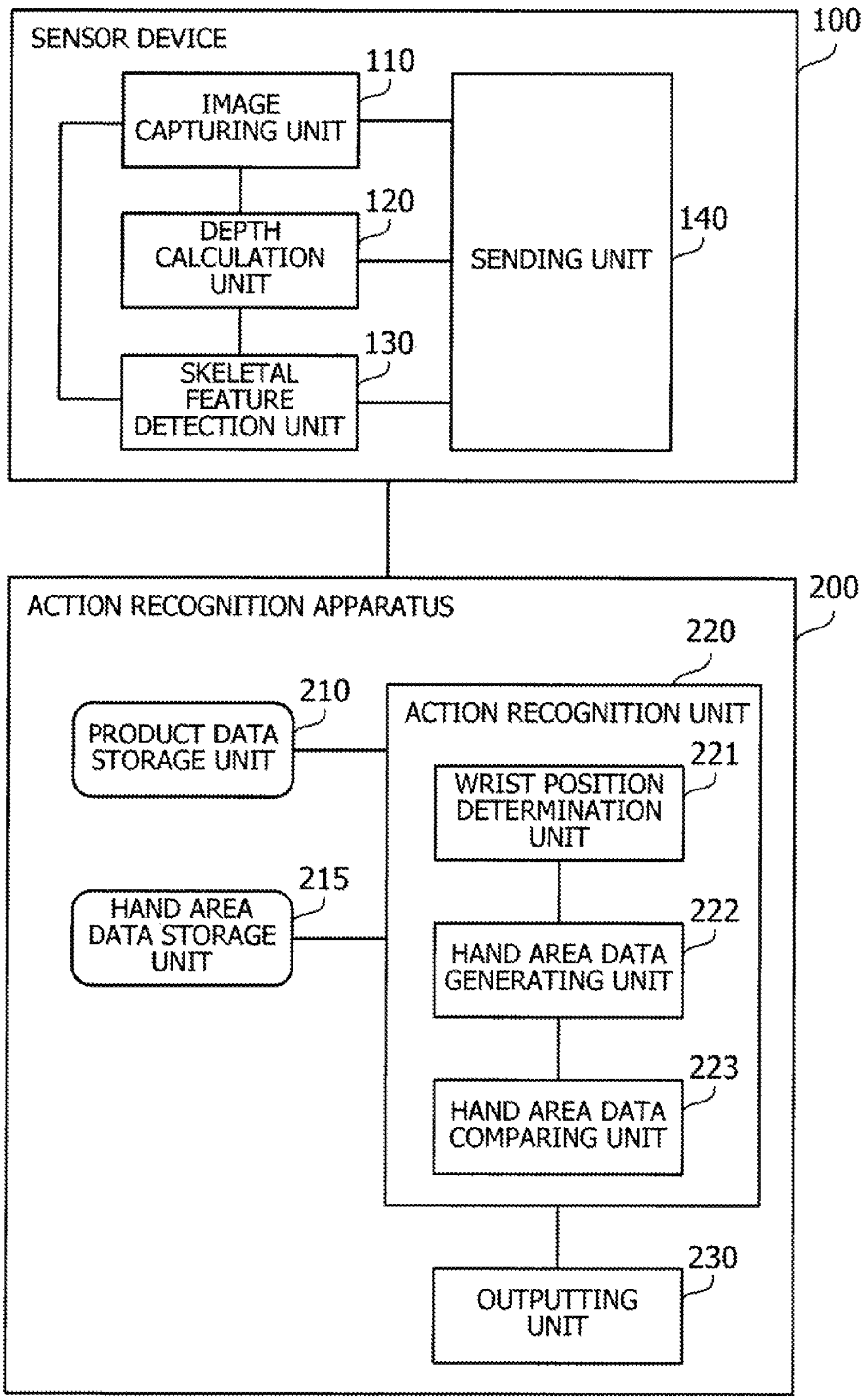
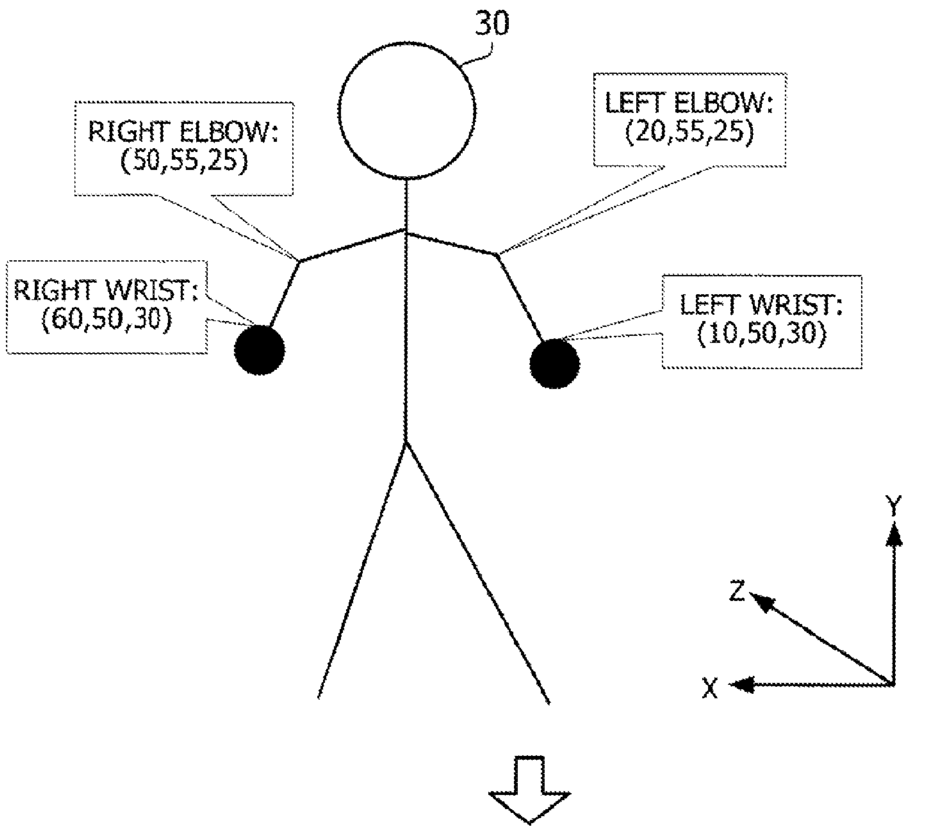

SENSOR DEVICE
100
110
IMAGE CAPTURING UNIT
120
DEPTH CALCULATION UNIT
130
SKELETAL FEATURE DETECTION UNIT
140
SENDING UNIT
ACTION RECOGNITION APPARATUS
200
220
ACTION RECOGNITION UNIT
210
PRODUCT DATA STORAGE UNIT
215
HAND AREA DATA STORAGE UNIT
221
WRIST POSITION DETERMINATION UNIT
222
HAND AREA DATA GENERATING UNIT
223
HAND AREA DATA COMPARING UNIT
230
OUTPUTTING UNIT

FIG. 10



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SKELETAL DATA		
CUSTOMER ID	SKELETAL PART	POSITION
CUSTOMER#1	RIGHT WRIST	(60,50,30)
	LEFT WRIST	(10,50,30)
	RIGHT ELBOW	(50,55,25)
	LEFT ELBOW	(20,55,25)
	⋮	⋮

FIG. 11

211

PRODUCT DATA TABLE	
PRODUCT ID	AREA DATA
PRODUCT#1	(25,10), (10,10), (15,20), (25,20)
PRODUCT#2	(40,10), (25,10), (25,20), (35,20)
⋮	⋮

FIG. 12

215a

HAND AREA DATA TABLE			
HAND AREA ID	STATE	DISTINCTIVE COLOR PIXEL COUNT	INDISTINCTIVE COLOR PIXEL COUNT
HAND AREA#1	IN	10000	0
HAND AREA#1	OUT	8000	2000
HAND AREA#2	IN	10000	0
⋮	⋮	⋮	⋮

FIG. 13

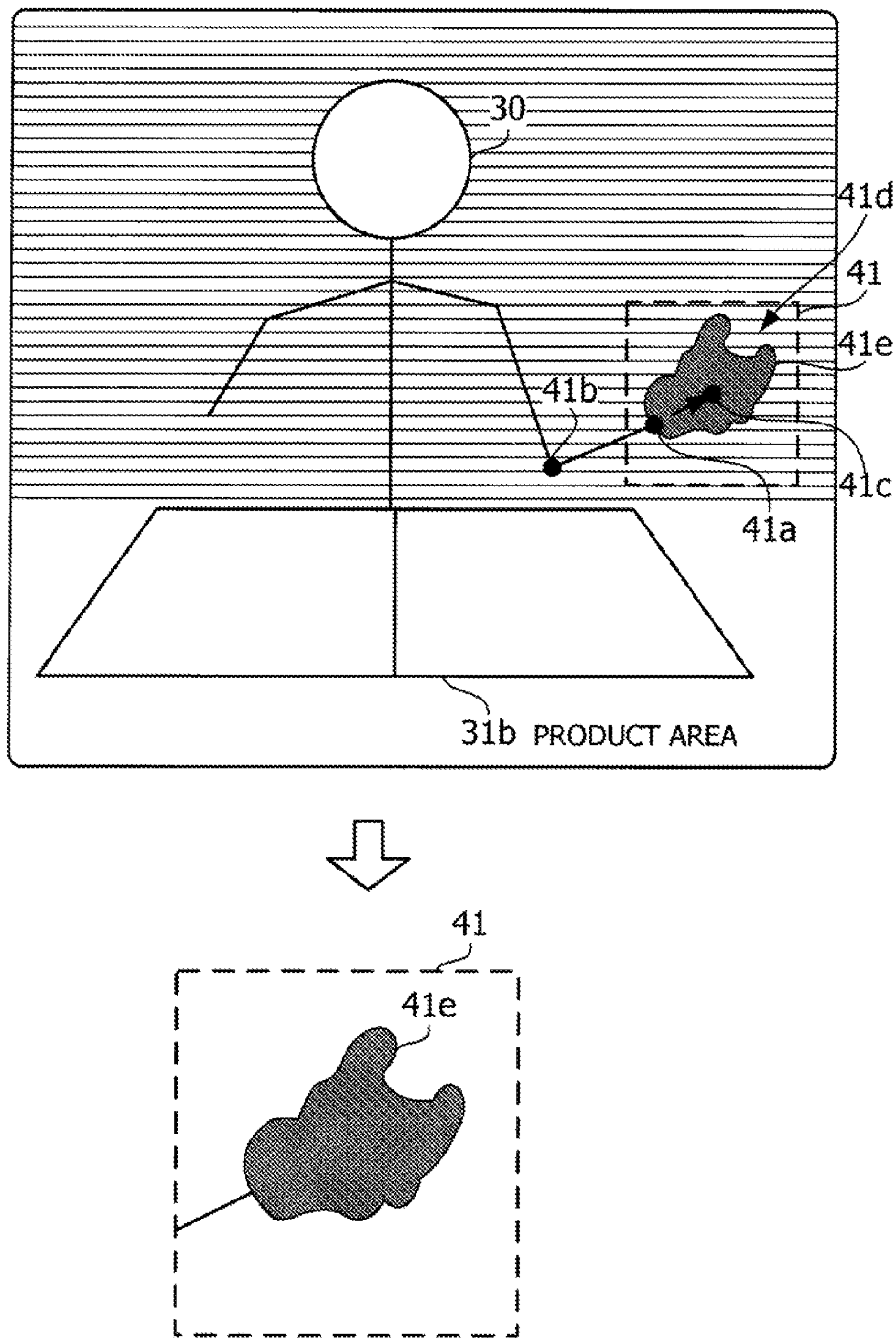


FIG. 14

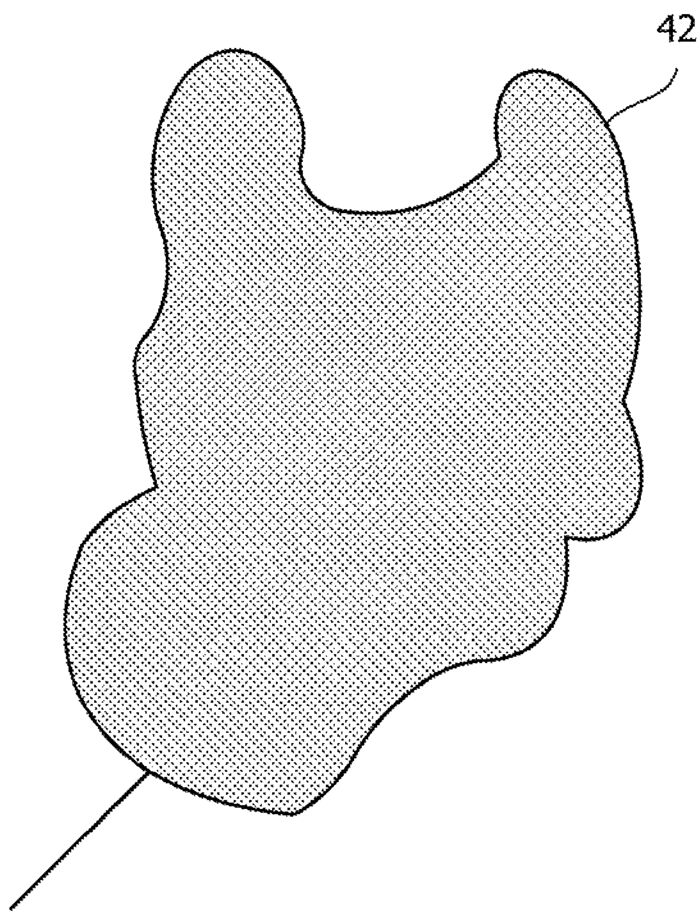


FIG. 15

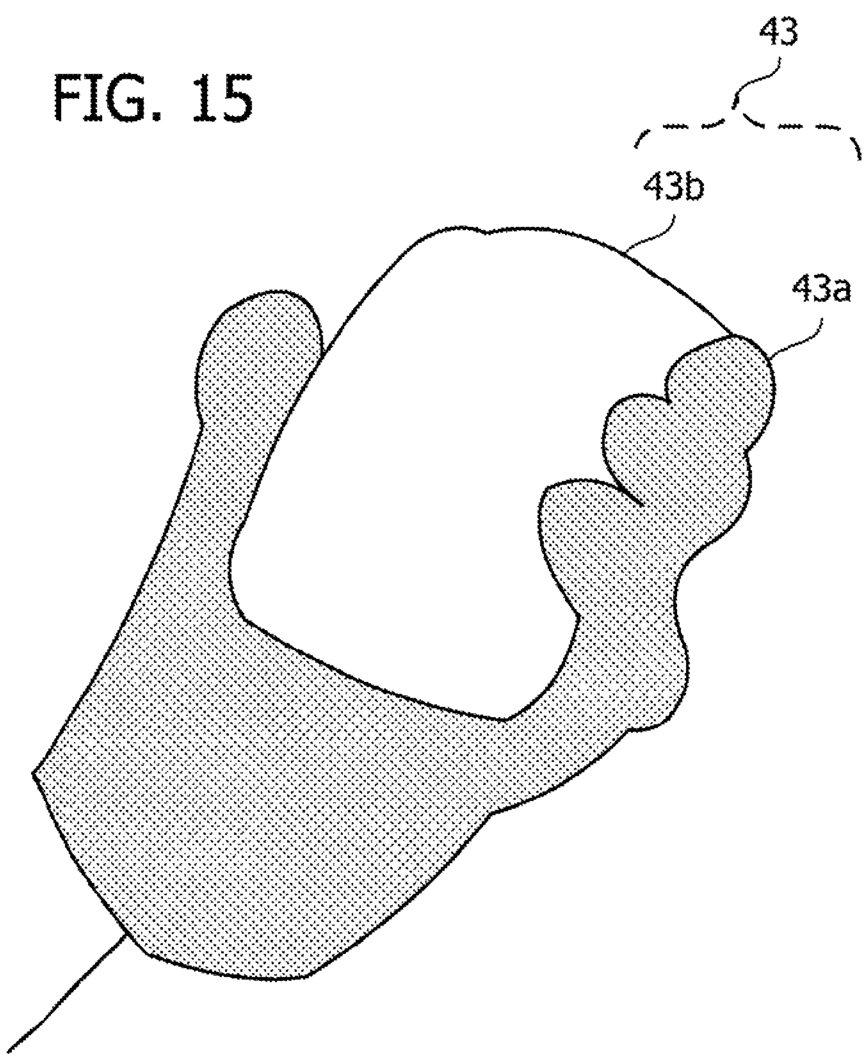


FIG. 16

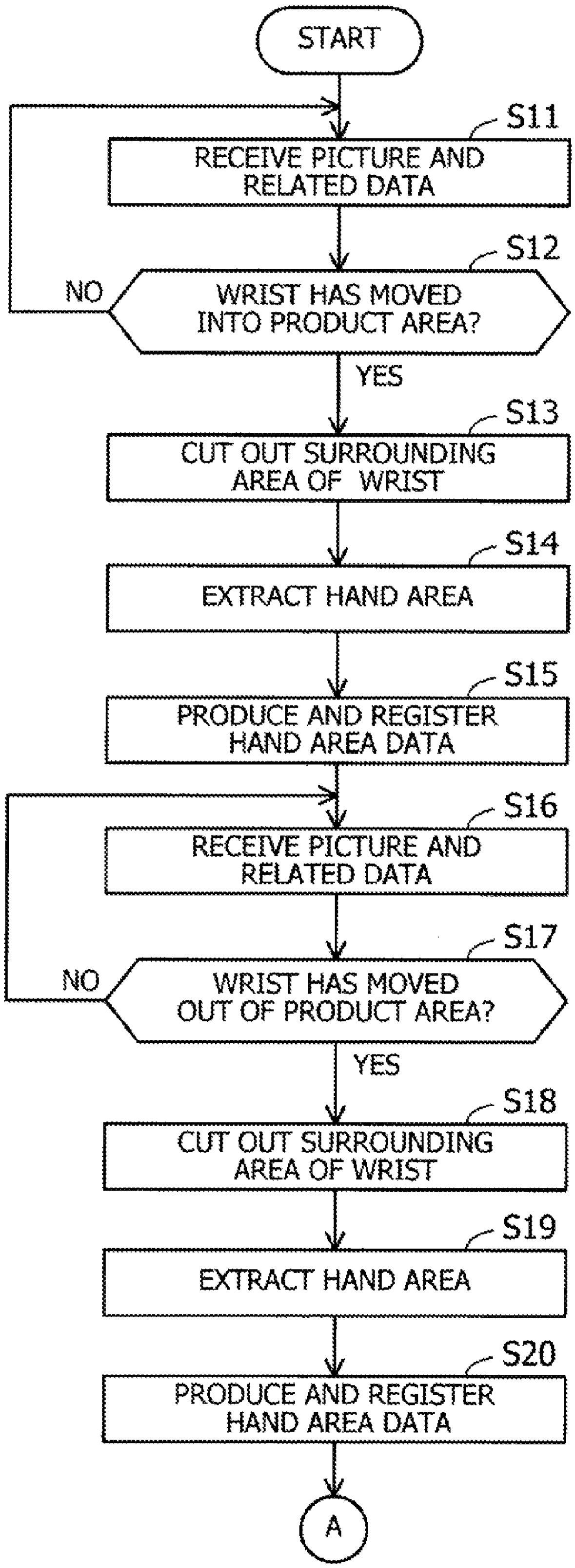

START
S11
RECEIVE PICTURE AND RELATED DATA
S12
WRIST HAS MOVED INTO PRODUCT AREA?
NO
YES
S13
CUT OUT SURROUNDING AREA OF WRIST
S14
EXTRACT HAND AREA
S15
PRODUCE AND REGISTER HAND AREA DATA
S16
RECEIVE PICTURE AND RELATED DATA
S17
WRIST HAS MOVED OUT OF PRODUCT AREA?
NO
YES
S18
CUT OUT SURROUNDING AREA OF WRIST
S19
EXTRACT HAND AREA
S20
PRODUCE AND REGISTER HAND AREA DATA
A

FIG. 17

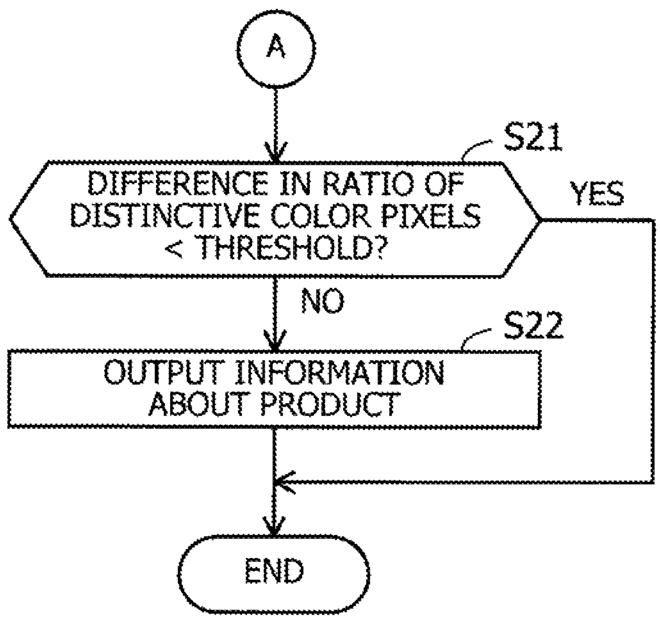
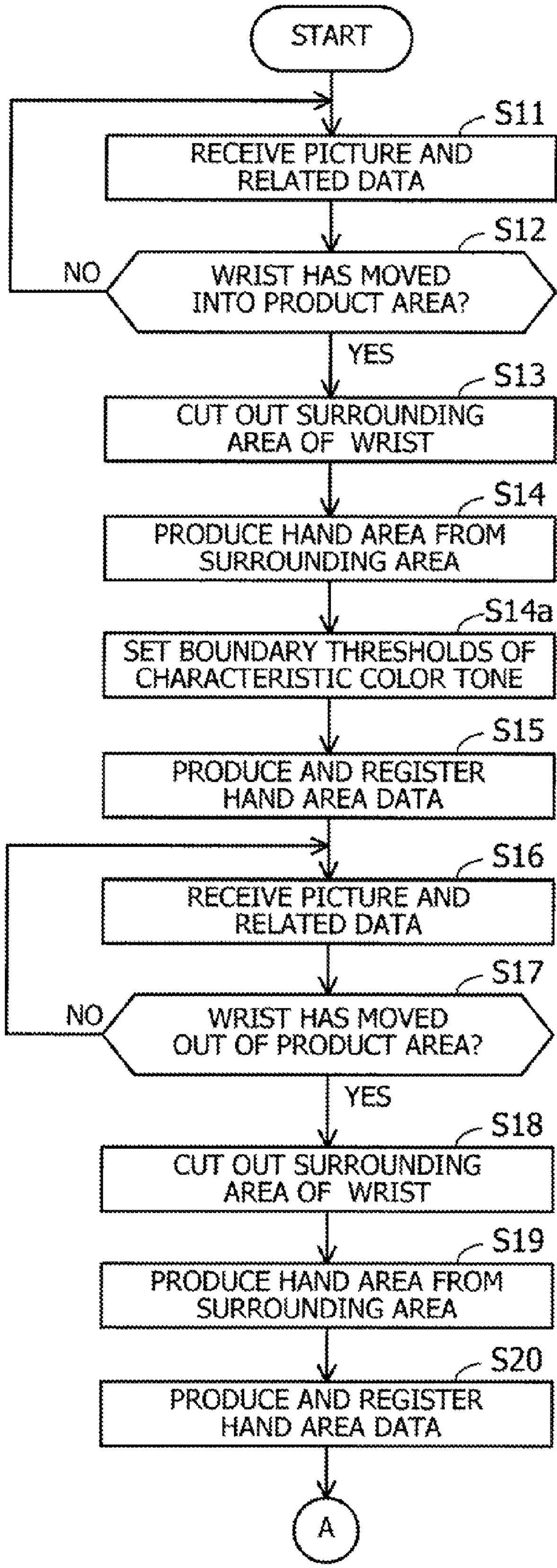

A
S21
DIFFERENCE IN RATIO OF DISTINCTIVE COLOR PIXELS < THRESHOLD?
YES
NO
S22
OUTPUT INFORMATION ABOUT PRODUCT
END

FIG. 18


START
S11
RECEIVE PICTURE AND RELATED DATA
S12
WRIST HAS MOVED INTO PRODUCT AREA?
NO
YES
S13
CUT OUT SURROUNDING AREA OF WRIST
S14
PRODUCE HAND AREA FROM SURROUNDING AREA
S14a
SET BOUNDARY THRESHOLDS OF CHARACTERISTIC COLOR TONE
S15
PRODUCE AND REGISTER HAND AREA DATA
S16
RECEIVE PICTURE AND RELATED DATA
S17
WRIST HAS MOVED OUT OF PRODUCT AREA?
NO
YES
S18
CUT OUT SURROUNDING AREA OF WRIST
S19
PRODUCE HAND AREA FROM SURROUNDING AREA
S20
PRODUCE AND REGISTER HAND AREA DATA
A

METHOD AND APPARATUS FOR RECOGNIZING ACTIONS

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2013-247978, filed on Nov. 29, 2013, the entire contents of which are incorporated herein by reference.

FIELD

The embodiments discussed herein relate to a method and an apparatus for recognizing actions.

BACKGROUND

Recent developments in the field of action recognition technology have enabled detection of particular actions that a person may perform, on the basis of pictures or videos taken by an imaging device. A part of such development efforts has been directed to techniques for determining whether a person has picked up an object. Such actions may be detected by analyzing data of pictures containing images of a person.

For example, one proposed technique extracts some appropriate areas from a given picture to detect entry or exit of a human hand, examines the three-dimensional position of a hand in each of the extracted areas, and determines whether an object has been taken out of its original place, on the basis of variations in the top-edge width of an area containing the hand. Another proposed technique captures frame images of, for example, a product shelf and evaluates frame-to-frame differences to detect whether a product is picked up from the shelf. See, for example, the documents listed below.

Japanese Laid-open Patent Publication No. 2001-128814

Japanese Laid-open Patent Publication No. 2011-253344

The above-described conventional techniques may, however, exhibit some inaccuracy in particular cases. For example, the technique based on frame-to-frame differences may mistakenly detect that a product is picked up in the case where the product has actually fallen off the shelf as a result of an accidental contact with a customer's body.

SUMMARY

In one aspect of the embodiments discussed herein, there is provided a method for recognizing actions by using an information processing apparatus. This method includes: obtaining, by the information processing apparatus, a picture containing an image of a person from an imaging device, as well as first data indicating distance of the person and other subjects seen in the picture from the imaging device on an individual pixel basis, second data indicating distance of a wrist of the person from the imaging device, and third data indicating a coordinate position of the wrist in the picture; extracting, by the information processing apparatus, a set of pixels from the obtained picture whose respective coordinates fall within a specified coordinate range defined around the coordinate position of the wrist and whose respective distances fall within a specified distance range defined around the distance of the wrist; and determining, by the information processing apparatus, whether the person has picked up an object, based on a ratio representing how many of the extracted pixels have a distinctive color tone.

The object and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** illustrates an exemplary process executed by an information processing apparatus according to a first embodiment;

FIG. **2** illustrates an example of an action recognition system according to a second embodiment;

FIG. **3** illustrates an exemplary arrangement of a sensor device;

FIG. **4** is a block diagram illustrating an exemplary hardware configuration of a sensor device;

FIG. **5** is a block diagram illustrating an exemplary hardware configuration of an action recognition apparatus;

FIG. **6** illustrates a first exemplary picture in which an action is detected;

FIG. **7** illustrates a second exemplary picture in which a subsequent action is detected;

FIG. **8** illustrates a third exemplary picture in which another subsequent action is detected;

FIG. **9** is a block diagram illustrating exemplary functions of the sensor device and action recognition apparatus;

FIG. **10** illustrates an example of skeletal data;

FIG. **11** illustrates an example of a product data table;

FIG. **12** illustrates an example of a hand area data table;

FIG. **13** illustrates an example of extraction of a hand area;

FIG. **14** illustrates a hand area image of a customer in the case where no products are held in his or her hand;

FIG. **15** illustrates another hand area image of the same customer when a product is held in his or her hand;

FIGS. **16** and **17** are a flowchart illustrating an example of how to recognize a customer holding a product; and

FIG. **18** is a flowchart illustrating an exemplary process according to a third embodiment to recognize a customer holding a product.

DESCRIPTION OF EMBODIMENTS

Several embodiments will be described below with reference to the accompanying drawings.

(a) First Embodiment

FIG. **1** illustrates an exemplary process executed by an information processing apparatus according to a first embodiment. Seen in the middle part of FIG. **1** is an imaging device **1** that takes still or video pictures in a specific view field to which it is directed. Pictures captured by the imaging device **1** are sent to an information processing apparatus **2** so as to determine whether a person seen in the pictures has picked up a particular object. This information processing apparatus **2** may be, for example, a computer or other processing devices.

Specifically, the information processing apparatus **2** receives data of a picture captured by the imaging device **1**, which contains an image of a person and one or both of his or her wrists. The information processing apparatus **2** obtains the distance of each such subject from the imaging device **1**. This distance information is provided for each individual pixel constituting the picture. The information processing apparatus **2** also obtains the distance of a coordinate point representing the person's wrist from the imaging device **1**.

The information processing apparatus **2** may obtain these pieces of data directly from the imaging device **1** or via a storage medium. The imaging device **1** may be configured to measure the two kinds of distances noted above and send them to the information processing apparatus **2**. Alternatively, a separate distance sensing device (not illustrated) may be used to perform the measurement and send the result to the information processing apparatus **2**.

The following description may use the term "wrist coordinate" to refer to the above-noted coordinate point representing the position of a wrist of a person. The description may also use the term "wrist distance" to refer to the above-noted distance of the wrist coordinate from the imaging device **1**.

The information processing apparatus **2** extracts a set of pixels from the obtained picture whose respective coordinates fall within a specified coordinate range around the wrist coordinate, and whose respective distances fall within a specified distance range around the wrist distance. The extracted pixels may include pixels whose color code values indicate a distinctive color tone. Based on the ratio of those pixels having a distinctive color tone to all the extracted pixels, the information processing apparatus **2** determines whether the person has picked up an object.

Referring to the specific example illustrated in FIG. **1**, the following description explains how the information processing apparatus **2** recognizes an action. It is assumed that the information processing apparatus **2** has obtained data of a picture **10** captured by the imaging device **1**, including an image of a person (subject), as well as the distance of that person from the imaging device **1** at each individual pixel and the distance of a coordinate point representing his or her wrist **11***a* from the imaging device **1**.

As seen in the upper half of FIG. **1**, the picture **10** is formed from images of the following distinct subjects: person **11**, object **12** and background **13**. The picture **10** has a specified coordinate range **14** defined as, for example, an area of pixels around the coordinate of the wrist **11***a* of the person **11**, with a fixed height and a fixed width. This specified coordinate range **14** contains at least one hand of the person **11** and its surrounding area. In the case where the person **11** holds an object **12** in his or her hand, it is highly likely that the specified coordinate range **14** also contains an image of the object **12**.

Relative to the position of the imaging device **1**, a range of distance may be specified as, for example, an area around the position of one wrist **11***a* of the person **11**. This specified distance range contains at least one hand of the person **11** and its surrounding area. In the case where the person **11** holds an object **12** in his or her hand, it is highly likely that the specified distance range contains the distance of that object **12**. The distance between the background **13** and imaging device **1**, on the other hand, does not usually fall within the specified distance range around the wrist **11***a*.

The information processing apparatus **2** extracts a set of pixels whose coordinates fall within the specified coordinate range **14** and whose distances fall within the specified distance range (step **S1**). Specifically, this step **S1** extracts a set of pixels **15** from the specified coordinate range **14**, excluding pixels of the background **13** whose distances are out of the specified distance range.

The image of the person **11** may contain several chunks of pixels representing his or her exposed skin. These pixels have a distinctive color tone, such as pale orange or the like, whereas the pixel representing an object **12** do not. The information processing apparatus **2** calculates a ratio of pixels having a distinctive color tone to the extracted set of pixels **15**. In other words, this ratio indicates how much part of the extracted set of pixels **15** represents the skin of the person **11**.

The information processing apparatus **2** now determines whether the person **11** has picked up an object **12**, based on the calculated ratio of pixels having a distinctive color tone (**S2**). More specifically, the pixels having a distinctive color tone make up a certain population in the extracted set of pixels **15** when the hands of the person **11** are empty. The ratio of such distinctive pixels goes down when the person **11** takes hold of an object **12**. The information processing apparatus **2** thus compares the calculated ratio with, for example, a previously given threshold. If the ratio falls below the threshold, the information processing apparatus **2** recognizes that the person **11** has picked up an object **12**.

The information processing apparatus **2** may be configured to execute the above calculation of pixel ratios on two occasions and compare the two ratios. For example, the first occasion is when one hand of the person **11** of interest enters a specific area where an object **12** lies. The second occasion is when the hand exits from the same specific area. Then based on the difference between these two ratios, the information processing apparatus **2** determines whether the person **11** has picked up an object **12**.

As mentioned previously, there is a proposed technique that relies on the differences between frame images captured by an imaging device to determine whether an object is picked up. This conventional technique, while applicable to the case illustrated in FIG. **1**, could mistakenly determine that a person has picked up a product if the person unintentionally touched a product and moved it out of the frame range of the imaging device **1**.

In contrast, the proposed information processing apparatus **2** of the first embodiment monitors the ratio that indicates how many of the pixels **15** extracted from a picture **10** have a distinctive color tone. Based on this ratio, the information processing apparatus **2** determines whether the person **11** of interest has picked up an object **12**. The object **12** may be moved to a place out of the frame due to the person's contact with the object **12** or may happen to move from its intended location. In these cases, the pixels representing the object **12** would not be contained in the specified coordinate range **14**. For this reason, the information processing apparatus **2** would not misinterpret such movement of the object **12** as a grasping action by the person **11**. The proposed information processing apparatus **2** thus achieves the purpose with a better accuracy.

As can be seen from the above explanation, the information processing apparatus **2** obtains the distance between the imaging device **1** and the wrist **11***a* seen in the picture **10** and extracts from a specified coordinate range a set of pixels **15** whose respective distances fall within a specified distance range. The information processing apparatus **2** classifies these pixels depending on whether they have a distinctive color tone. The load of this pixel classification task is not significant because the task is performed only within a limited set of pixels **15** in which a hand is supposed to be seen. The smallness of this set of pixels **15** means an increase in the relative share of pixels having a distinctive color tone, which contributes to more accurate determination of whether an object **12** has been picked up.

It is further noted that the proposed method relies not on the number of pixels having a distinctive color tone, but on the ratio of such pixels in the extracted set of pixels **15**. This difference makes it possible to detect an object **12** being held in a hand, regardless of the angle of the wrist **11***a* in the picture **10**.

(b) Second Embodiment

FIG. **2** illustrates an example of an action recognition system according to a second embodiment. The illustrated action recognition system **3** includes a sensor device **100** and an action recognition apparatus **200**, both located in a retail shop of particular products. It is also possible to place the sensor device **100** alone in the shop, with a connection to the action recognition apparatus **200** located in other premises. The sensor device **100** may have various functions, part of which works as an implementation of the imaging device **1** discussed in the first embodiment. The action recognition apparatus **200** is an implementation of the foregoing information processing apparatus **2** of the first embodiment.

The sensor device **100** has the function of capturing pictures of at least an area in the shop space where products are displayed for sale. For example, the sensor device **100** may be directed at a particular product showcase (not illustrated). The sensor device **100** is also capable of measuring the depth of each pixel in captured pictures and outputting the measurements as depth data. The term "depth" refers to the distance of each pixel of the captured subject relative to the sensor device **100**.

The sensor device **100** further analyzes skeletal features of a person (who is a customer or consumer in the present context) seen in the picture. Specifically, the sensor device **100** detects at least wrists and elbows of the customer and outputs skeletal data indicating them. More specifically, the skeletal data includes information on the position of each detected skeletal feature. The position information includes the in-picture coordinates (i.e., local coordinates within a picture) and the depths of skeletal features.

The sensor device **100** transmits its output data to the action recognition apparatus **200**, which includes data of captured pictures, measured depths of each pixel, and skeletal data of detected features. This data transmission from the sensor device **100** may be performed at predetermined time intervals.

The action recognition apparatus **200** is actually a computer configured to recognize particular behavior of customers. Each time a new picture arrives from the sensor device **100** along with some related data, the action recognition apparatus **200** analyzes the received skeletal data, picture data, and the like to determine whether a customer seen in the picture has picked up a product. When such behavior of a customer is detected, the action recognition apparatus **200** outputs information about the product to a display device or records it in a log file.

What is detected by the action recognition apparatus **200** is not limited to the example described above, but may vary with demand. For instance, the action recognition apparatus **200** may be programmed to detect that a person has simply passed in front of products, or has directed his or her attention to a product, or has manifested interest in a product.

FIG. **3** illustrates an exemplary arrangement of a sensor device. As seen in FIG. **3**, a product **32** is placed on top of a showcase **31**, and the space on the right-hand side is where customers are allowed to walk around. A sensor device **100** is situated on the opposite side of the showcase **31**, so that its view field will cover the showcase **31**, product **32**, and a customer **30** (if any). The sensor device **100** takes pictures of these subjects and sends data of these pictures, together with depth data of each pixel and skeletal data of the customer **30**, to the action recognition apparatus **200**.

FIG. **4** is a block diagram illustrating an exemplary hardware configuration of a sensor device. The illustrated sensor device **100** includes a processor **101**, a random access memory (RAM) **102**, a flash memory **103**, an imaging camera **104**, a depth sensor **105**, and a communication interface **106**. All these components are connected to a bus **107** in the sensor device **100**.

The processor **101** (e.g., central processing unit, or CPU) contains computation units to execute instructions encoded in software programs. The processor **101** reads at least part of program and data files stored in the flash memory **103** and executes programs after loading them on the RAM **102**. A plurality of such processors may be integrated into a single processor **101**. The sensor device **100** may include a plurality of processors or a plurality of processor cores to execute multiple programs in parallel. The term "processor" denotes a broad range of processing devices including field-programmable gate array (FPGA), application specific integrated circuit (ASIC), and other electronic circuits dedicated or programmed for specific purposes, as well as a combination of two or more such devices. The term "processor" may also refer to a combination of a general-purpose processor and such special-purpose devices.

The RAM **102** serves as a temporary memory for programs that the processor **101** executes, as well as for various data that the processor **101** refers to when executing programs. The sensor device **100** may have other kinds of volatile memory devices, without limitation in the number of such devices.

The flash memory **103** serves as a non-volatile storage device to store program and data files of firmware, applications, and other kinds of software. The sensor device **100** may have a plurality of non-volatile storage devices, including those of other types such as hard disk drive (HDD), in place of or together with the flash memory **103**. Programs for the processor **101** may be copied from other storage devices to the flash memory **103**.

The imaging camera **104** takes pictures and sends their data to the processor **101**. The depth sensor **105** measures the depth of each pixel in the picture taken by the imaging camera **104** and sends measurement data to the processor **101**. Various techniques are available to measure the depth of a remote object. Time of flight (TOF) method is one of those measurement techniques, which calculates the depth from round-trip time of laser light. As another such technique, the pattern projection method utilizes deformation of a pattern that reflected rays (e.g., infrared rays) make. To implement one of these methods, the depth sensor **105** is equipped with a light emitting device for laser or infrared rays and a light sensing device to receive reflection of the emitted light.

The communication interface **106** permits the processor **101** to communicate with other devices, such as the action recognition apparatus **200** as seen in FIG. **4**.

An exemplary hardware configuration of the sensor device **100** has been described above. To name a more specific example, Kinect® sensor from Microsoft Corporation may be used as the sensor device **100**.

FIG. **5** is a block diagram illustrating an exemplary hardware configuration of an action recognition apparatus. The illustrated action recognition apparatus **200** includes a processor **201**, a RAM **202**, an HDD **203**, a video signal processing unit **204**, an input signal processing unit **205**, a disc drive **206**, and a communication interface **207**. All these components are connected to a bus **208** in the action recognition apparatus **200**.

The processor **201** contains computation units to execute instructions encoded in software programs, just as does the foregoing processor **101** in the sensor device **100**. The RAM **202** is a volatile memory device serving as temporary storage for programs and data that the processor **201** executes or uses, just as does the foregoing RAM **102**.

The HDD **203** works as a non-volatile storage device to store program and data files of the operating system (OS), firmware, applications, and other kinds of software. The action recognition apparatus **200** may have a plurality of non-volatile storage devices, including those of other types such as flash memory, in place of or together with the HDD **203**.

The video signal processing unit **204** produces video images in accordance with commands from the processor **201** and displays them on a screen of a display **21** coupled to the action recognition apparatus **200**. The display **21** may be, for example, a cathode ray tube (CRT) display or a liquid crystal display.

The input signal processing unit **205** receives input signals from input devices **22** attached to the action recognition apparatus **200** and supplies the received signals to the processor **201**. The input devices **22** may be, for example, a keyboard and a pointing device such as mouse and touchscreen.

The disc drive **206** is a device used to read programs and data stored in storage media **23**. The storage media **23** include, for example, magnetic disk media such as flexible disk (FD) and HDD, optical disc media such as compact disc (CD) and digital versatile disc (DVD), and magneto-optical storage media such as magneto-optical disc (MO). The disc drive **206** transfers programs and data read out of storage media **23** to, for example, the RAM **202** or HDD **203** according to commands from the processor **201**.

The communication interface **207** permits the processor **201** to communicate with other devices, such as the sensor device **100** as seen in FIG. **5**.

The above-described hardware configuration of the action recognition apparatus **200** may have some variations. For example, the disc drive **206** may be omitted from the action recognition apparatus **200**. The video signal processing unit **204** and input signal processing unit **205** may also be omitted in the case where the action recognition apparatus **200** is not a stand-alone device, but wholly controlled by a remote terminal station. As yet another variation, the action recognition apparatus **200** may share its enclosure with the display **21** and input device **22**.

Referring next to FIGS. **6** to **8**, the following description will present a comparative method for determining whether a customer has picked up a product, and discuss some drawbacks of the method. This is only for the purpose of comparison with the proposed method of the embodiments, but not intended to limit the embodiments. The comparative method starts with taking pictures with an imaging device. More specifically, one picture is taken when a hand has entered a predetermined area, and another picture is taken when the same hand has left the predetermined area. These pictures are compared by an action recognition apparatus to check the position of a product seen in the pictures. When a change is found in the position of the product, the action recognition apparatus determines that the customer seen in the pictures has picked up the product.

FIG. **6** illustrates a first exemplary picture in which an action is detected. Two areas are defined on the table top of a product showcase, which are referred to as first and second areas **31***a* and **31***b* as seen in FIG. **6**. Different products may be placed in these two areas **31***a* and **31***b*. In the exemplary picture **4** of FIG. **6**, however, one product **32** is seen in the second area **31***b*. The picture **4** is taken when a customer **30** has moved his or her left hand into the second area **31***b*. The action recognition apparatus receives data of this picture **4** from the imaging device.

FIG. **7** illustrates a second exemplary picture in which a subsequent action is detected. This picture **5** is taken by the imaging device after the action recognition apparatus has received the previous picture **4**. More specifically, the new picture **5** depicts that the customer **30** has moved his or her left hand out of the second area **31***b*, with the product **32** in it. The action recognition apparatus receives data of this picture **5** from the imaging device.

The action recognition apparatus compares the two received pictures **4** and **5**, thereby detecting that the product **32** is not present in the area **31***b*. With the absence of the product **32**, the action recognition apparatus determines that the customer **30** has picked up the product **32**.

FIG. **8** illustrates a third exemplary picture in which another subsequent action is detected. Illustrated is another possible picture **6** taken by the imaging device after the action recognition apparatus has received the previous picture **4**. Specifically, the picture **6** depicts that the customer **30** has moved his or her left hand out of the second area **31***b*. Unlike the picture **5** discussed in FIG. **7**, the product **32** is not in the hand of the customer **30**, but has fallen and rolled on the table top into the first area **31***a*. This situation can happen if the product **32** is accidentally hit by some part of the body of the customer **30** or by a bag the customer **30** is carrying. The action recognition apparatus receives data of this picture **6** from the imaging device. The action recognition apparatus compares the two received pictures **4** and **6**, thereby detecting absence of the product **32** in the area **31***b*. The action recognition apparatus mistakenly interprets this absence of the product **32** as indicating that the customer **30** has picked up the product **32**.

The comparative method described above in FIGS. **6** to **8** relies on the difference between pictures. This method may, however, determine that a customer has picked up a product, although the fact is that his or her empty hand has moved out of a predetermined area. As this example demonstrates, the comparative method is susceptible to improvement in terms of accuracy of determination.

The proposed action recognition system **3** of the present embodiment is designed to reduce the chances of such misinterpretation of images. Referring now to FIG. **9** and subsequent drawings, the following section describes a method that the action recognition system **3** executes to recognize a customer picking up a product.

FIG. **9** is a block diagram illustrating exemplary functions of the sensor device and action recognition apparatus. Referring first to the upper half of FIG. **9**, the illustrated sensor device **100** includes an image capturing unit **110**, a depth calculation unit **120**, a skeletal feature detection unit **130**, and a sending unit **140**. See also FIG. **4** for other components in the sensor device **100**.

The image capturing unit **110** obtains picture data from an imaging camera **104** at predetermined intervals.

The depth calculation unit **120** calculates depth of each pixel in the captured picture on the basis of measurement data of a depth sensor **105**. Each time the image capturing unit **110** obtains new picture data, the depth calculation unit **120** repeats this depth calculation and produces depth data indicating the depth of pixels.

The skeletal feature detection unit **130** analyzes picture data and depth data to detect the skeletal positions of previously specified parts (e.g., wrists, elbows, head, and shoulders) of a person seen in the picture. Each time the image capturing unit **110** obtains new picture data, the skeletal feature detection unit **130** detects the skeletal positions of body parts and outputs skeletal data including position data indicating each skeletal part of interest. The position data of a body part includes its coordinates in the picture and its distance (depth) from the sensor device **100**. When the picture contains images of two or more persons, the skeletal feature detection unit **130** may produce skeletal data for each individual person.

The sending unit **140** sends the action recognition apparatus **200** the data of pictures taken and their depth data, as well as skeletal data if any person's image is included in the pictures.

The above image capturing unit **110**, depth calculation unit **120**, skeletal feature detection unit **130**, and sending unit **140** may be implemented as part of the functions that the processor **101** offers by executing programs.

Referring to the lower half of FIG. **9**, the illustrated action recognition apparatus **200** include a product data storage unit **210**, a hand area data storage unit **215**, an action recognition unit **220**, and an outputting unit **230**.

The product data storage unit **210** is where a product data table is stored. This product data table is a collection of information about products sold at a retail shop in which the action recognition system **3** is deployed. The product data storage unit **210** may be implemented as, for example, a non-volatile storage space secured in the HDD **203** or the like.

The hand area data storage unit **215** stores a hand area data table, which is a collection of information about hands of a customer. A hand area is defined around the position of a person's wrist. More specifically, a hand area is a collection of pixels that are extracted from a specified area surrounding the wrist coordinate as having depths in a specific depth range. The pixels in a hand area include those with a distinctive color tone (e.g., pale orange). The hand area data table stored in the hand area data storage unit **215** indicates, among other things, the number of those distinctive color pixels and the number of other pixels than the distinctive color pixels, as will be discussed in detail later. The hand area data table is produced for temporary use when the action recognition unit **220** performs its tasks. The hand area data storage unit **215** may be implemented as, for example, a storage space secured in the RAM **202**.

The action recognition unit **220** determines whether the customer has picked up a product, on basis of information received from the sensor device **100**. To achieve this, the action recognition unit **220** includes a wrist position determination unit **221**, a hand area data generating unit **222**, and a hand area data comparing unit **223**.

The wrist position determination unit **221** analyzes given pictures to determine whether the customer's wrist has entered or has left a particular area where a product is placed, based on the picture data and skeletal data received from the sensor device **100**.

The hand area data generating unit **222** produces hand area data from image data, depth data, and skeletal data at the moment when the customer's wrist enters the product area. The hand area data generating unit **222** does the same when the customer's wrist goes out of the product area. These pieces of hand area data are recorded in a hand area data table.

The hand area data comparing unit **223** compares two records of hand area data with each other, one at the time of entry to the product area and the other at the time of exit from the product area. Based on the result of this comparison, the hand area data comparing unit **223** determines whether the customer has picked up the product in the area.

The outputting unit **230** outputs information about a product when the hand area data comparing unit **223** determines that the customer has picked up that product.

The above wrist position determination unit **221**, hand area data generating unit **222**, hand area data comparing unit **223**, and outputting unit **230** may be implemented as part of the functions that the processor **201** offers by executing programs.

Referring to FIGS. **10** to **12**, the following section describes what information and tables are used in the action recognition system **3**.

FIG. **10** illustrates an example of skeletal data. Skeletal data **131** is produced by the skeletal feature detection unit **130** to offer the positions of several skeletal portions, such as elbows and wrists, of a customer. Specifically, the skeletal data **131** is formed from the following data fields: Customer Identifier (ID), Skeletal Part, and Position.

The customer ID field contains an identifier that distinguishes each particular customer seen in pictures. The skeletal part field contains the distinguishing name of each specified part of the customer's body. The position field indicates the position of each specified part of the customer's body, which is represented as the coordinates (X, Y, Z) with respect to the optical axis of the imaging camera **104** in the action recognition system **3**. X axis is a horizontal axis running perpendicular to the optical axis, whose leftward direction is positive when viewed from the imaging camera **104**. Y axis is a vertical axis running perpendicular to the optical axis, whose upward direction is positive when viewed from the imaging camera **104**. Z axis runs on the optical axis in the direction away from the imaging camera **104**. X-Y coordinates represent each point of skeletal parts seen in a picture, while Z coordinates represent the depth of such points.

Referring to the example of FIG. **10**, the right wrist, left wrist, right elbow, left elbow, and other things of a customer are detected as his or her skeletal parts. For example, the right wrist of a customer **30** is detected at a coordinate point of (60, 50) with a depth of 30. This right wrist position is recorded as a value of (60, 50, 30) in the position field of the skeletal data **131**. The skeletal position may alternatively be represented in the form of latitude, longitude, and height.

FIG. **11** illustrates an example of a product data table. The illustrated product data table **211** is stored in the product data storage unit **210** to define in-picture areas corresponding to actual display locations of products in the retail shop. These in-picture areas are monitored to detect entry or exit of a customer's wrist. Specifically, the illustrated product data table **211** is formed from Product ID and Area Data fields.

The product ID field contains an identifier that distinguishes each product from others. The area data field contains position data that defines an in-picture area in which a product is placed. This area is referred to as a "product area."

The proposed action recognition system **3** assumes that the product areas are quadrangular in shape. The position data of a quadrangular product area is thus a set of four corner coordinates, each in the form of (X, Y) to indicate the X axis position and Y axis position of a corner point. The product ID and its corresponding area data may be user-defined.

Product areas may be in other shapes, such as circular or oval, although the ones defined in FIG. **11** are quadrangular. In the case of rectangular product areas, the area data may only specify the coordinates of upper-right and lower-left corners. It is also noted that the product data table **211** may contain more data fields, such as product names and the number of times that the product was picked up.

FIG. **12** illustrates an example of a hand area data table. The illustrated hand area data table **215***a* is temporarily stored in the hand area data storage unit **215** to record information about hand areas of customers. Specifically, the hand area data table **215***a* is formed from the following data fields: Hand Area ID, State, Distinctive Color Pixel Count, and Indistinctive Color Pixel Count.

The hand area ID field contains an identifier that distinguishes a hand area from others. Each registered hand area corresponds to a customer's wrist that has entered or left a product area. As will be described later, a hand area is a set of pixels whose depths fall within a specified range around the wrist in the picture. These pixels are extracted from a surrounding area of the wrist.

The state field indicates a recorded state of the wrist. More specifically, the state field contains either a value of "IN" to indicate that the wrist has entered a product area, or a value of "OUT" to indicate that the wrist has left a product area.

The distinctive color pixel count field indicates the number of hand-area pixels having a distinctive color tone. The description refers to such pixels as "distinctive color pixels," and their quantity as "distinctive color pixel count."

The indistinctive color pixel count field indicates the number of hand-area pixels whose color code does not fall in the range of distinctive color tone. The description refers to such pixels as "indistinctive color pixels," and their quantity as "indistinctive color pixel count."

The discrimination between a distinctive color pixel and an indistinctive color pixel is made by testing whether the color code of the pixel in question falls within a range demarcated by thresholds. The color code of pixels is expressed with a specific color model, such as Red Green Blue (RGB) model and Cyan Magenta Yellow (CMY) model. The color code may also be expressed as chrominance, or color-difference components.

As mentioned above, the distinctive color tone is specified as one or more definite color ranges demarcated by thresholds. A pixel will be determined to have a distinctive color tone when its color code falls within one of those color ranges. For example, the action recognition system **3** is configured to extract pale orange pixels as distinctive color pixels. The selection of a distinctive color tone, however, is not limited by this specific example.

Referring now to FIGS. **13** to **15**, the following description will explain in detail how the proposed method determines whether a product is picked up. It is assumed in FIGS. **13** to **15** that a customer **30** has moved his or her left wrist **41***a* out of a product area.

FIG. **13** illustrates an example of extraction of a hand area. Specifically, the picture seen in FIG. **13** includes a product area **31***b* with a quadrangular shape, which has been registered in the product data table **211**. The wrist position determination unit **221** observes product areas, such as the illustrated product area **31***b* in FIG. **13**, to detect a human wrist when it appears in those areas. The position of a wrist, if any, in the picture is indicated in the form of X and Y coordinates, as part of position data included in the skeletal data. The wrist position determination unit **221** keeps track of the wrist position, thus detecting its entry into a product area and its exit from the same.

Upon detection of entry of a customer's wrist into a specific product area, as well as upon detection of its exit from that area, the hand area data generating unit **222** extracts a hand area by executing a procedure described below. What are seen in the exemplary picture of FIG. **13** are a customer **30** and his or her left wrist **41***a* and left elbow **41***b*. The following procedure is to extract a hand area corresponding to the left wrist **41***a*.

The hand area data generating unit **222** cuts out an image area **41** surrounding the left wrist **41***a* from the given picture as seen in the upper half of FIG. **13**. This surrounding area **41** has a rectangular shape with a predetermined size. Based on the position of the left wrist **41***a* and its corresponding left elbow **41***b* in the picture, the hand area data generating unit **222** calculates a point at which the center of the surrounding area **41** will be placed so as to contain the entire left hand of the customer **30**. Referring to the example seen in the upper half of FIG. **13**, the center point **41***c* of the surrounding area **41** is located on the straight line running from left elbow **41***b* to left wrist **41***a*, with a certain amount of offset beyond the left wrist **41***a*.

The action recognition unit **220** may alternatively be configured to calculate a center point **41***c* on the basis of the customer's wrist and hand positions. The action recognition unit **220** may also be configured to vary the size of the surrounding area **41** depending on the distance between the left wrist **41***a* and the left elbow **41***b*.

The hand area data generating unit **222** calculates a depth range for demarcating a hand area within the surrounding area **41**, based on the depth of the left wrist **41***a*. This range of depth may be referred to as a "hand depth range." For example, the hand area data generating unit **222** calculates a hand depth range of $(\alpha-\beta)$ to $(\alpha+\beta)$, where the symbol α denotes the wrist depth.

The hand area data generating unit **222** then extracts a hand area from the surrounding area **41** by removing pixels whose depths are not in the calculated hand depth range. Referring to the example seen in the upper half of FIG. **13**, the surrounding area **41** is formed from a foreground area **41***e* representing a hand and a background area **41***d* representing its background. The foreground area **41***e* can be distinguished as having depths within the hand depth range calculated on the basis of a left wrist **41***a* unlike the background area **41***d*. The hand area data generating unit **222** thus removes pixels whose depths are not in the hand depth range. The remaining pixels in the surrounding area **41** form a hand area as illustrated in the lower half of FIG. **13**.

FIG. **14** illustrates a hand-area image of the customer in the case where no products are held in his or her hand. FIG. **15** illustrates another hand area image of the customer when a product is held in his or her hand. It is assumed in both FIGS. **14** and **15** that a hand area has been extracted from a picture taken at the time of exit of the customer's wrist from a product area, and that the entire hand area is filled with distinctive color pixels. It is also assumed in both FIGS. **14** and **15** that the action recognition apparatus **200** is configured to recognize that a customer has picked up a product if the ratio of distinctive color pixels in a hand area is decreased by 20% or more at the time of exit from a product area, relative to the ratio at the time of entry into the same.

Here the customer **30** moves his or her left wrist **41***a* out of the product area **31***b* with nothing in his or her hand, and a picture is taken at the time of that movement. Illustrated in FIG. **14** is a hand area **42** extracted from the picture, which is entirely made up of distinctive color pixels. In other words, the ratio of distinctive color pixels in the hand area **42** is 100%. This means that there has been no change in the distinctive color pixel ratio since the entry of the wrist into the product area **31***b*. With the change being less than 20%, the action recognition apparatus **200** concludes that the customer **30** has no product in his or her hands.

In contrast to FIG. **14**, the hand area **43** seen in FIG. **15** has been extracted from the picture taken upon movement of the customer **30**'s left wrist **41***a* out of the product area **31***b* with a product held in his or her hand. The image of this hand area **43** includes a first area **43***a* of distinctive color pixels and a second area **43***b* of indistinctive color pixels. Suppose, for example, the first area **43***a* contains as many pixels as the second area **43***b*. The ratio of distinctive color pixels in the hand area **43** is 50% in this case, which means a change exceeding 20% with respect to the ratio (100%) at the time of entry to the product area **31***b*. Accordingly, the action recognition apparatus **200** recognizes that the customer **30** holds a product in his or her hand.

As can be seen from the above explanation of FIGS. **13** to **15**, the hand area data generating unit **222** extracts a hand area as a set of pixels whose respective depths fall within a specific depth range including the position of a customer's wrist, upon its entry to or exit from a product area. The hand area data generating unit **222** determines whether the customer has picked up a product, on the basis of a difference in the ratio of distinctive color pixels between the hand area at the time of entry into the product area and that at the time of exit from the same.

It may be an option for the hand area data generating unit **222** to determine whether a customer has picked up a product, on the basis of the number of distinctive color pixels in each hand area extracted at the time of entry into a product area and exit from the product area. This option, however, has a drawback in the accuracy of determination since the number of distinctive color pixels is affected by wrist angle variations at the moment of entry to and exit from a product area. The hand area data generating unit **222** is therefore designed to use, not the number, but the ratio of distinctive color pixels so as to avoid disturbance by such wrist angle variations.

It may be another option for the hand area data generating unit **222** to determine whether a customer has picked up a product, based on only one hand area extracted upon exit of his or her wrist from a product area. When this is the case, the hand area data generating unit **222** detects a product held in the customer's hand if, for example, the hand area contains distinctive color pixels whose share is less than a predetermined threshold. However, the image in a hand area could be misinterpreted when the hand area keeps a certain percentage of indistinctive color pixels, as in the case where the customer wears a long-sleeve shirt, for example. This is why the hand area data generating unit **222** is configured to compare two hand-area images extracted upon entry to a product area and upon exit from that product area. The proposed hand area data generating unit **222** thus makes accurate determination even when the hand area keeps a certain percentage of indistinctive color pixels.

FIGS. **16** and **17** are a flowchart illustrating an example of how to recognize that a customer has picked up a product. It is assumed that the customer's wrists are located outside the product area of interest when the process illustrated in FIGS. **16** and **17** is triggered. Each operation seen in FIGS. **16** and **17** will be described below in the order of step numbers.

(S**11**) The wrist position determination unit **221** receives a picture and depth data from the sensor device **100**. The wrist position determination unit **221** also receives skeletal data of a customer seen in the picture.

(S**12**) The wrist position determination unit **221** determines whether the customer's wrist has moved into a product area. The position of a wrist seen in the picture is obtained from the position field of the received skeletal data, which describes the right or left wrist. Information about product areas is available in the area data field of the foregoing product data table **211**. More specifically, the wrist position determination unit **221** determines whether the wrist position indicated by the received skeletal data has moved into one of the product areas registered in the product data table **211**.

When the wrist position is found to be in a product area, the process advances to step S**13**. When the wrist position is still out of the product areas, the process returns to step S**11**. In other words, the wrist position determination unit **221** repeats steps S**11** and S**12** until it receives a picture in which the customer's wrist is found in one of the product areas.

(S**13**) The hand area data generating unit **222** cuts out a surrounding area of the wrist from the received picture. That is, the customer's wrist is now in the product area. Based on the positions of the wrist and its corresponding elbow in the picture, the hand area data generating unit **222** calculates an image area surrounding the wrist as explained previously in the upper half of FIG. **13**.

To obtain the wrist and elbow positions for the above action, the hand area data generating unit **222** searches skeletal data for relevant records. That is, the wrist position is obtained from a skeletal data record that contains a value indicating the wrist seen in the product area. Similarly the elbow position is obtained from a skeletal data record that contains a value indicating the elbow corresponding to the wrist in question.

(S**14**) The surrounding area obtained at step S**13** contains an image of the customer's hand. The hand area data generating unit **222** extracts a hand area as a set of pixels whose respective depths are within a specified depth range including the position of the wrist. The depth range is defined on the Z axis, around the depth of the wrist, as explained previously in FIG. **13**.

(S**15**) The hand area data generating unit **222** counts distinctive color pixels and indistinctive color pixels in the extracted hand area. The determination of whether pixels have a distinctive color tone is made by comparing their color codes with several thresholds previously defined therefor.

The hand area data generating unit **222** then produces a record of hand area data by populating its hand area ID field, state field, distinctive color pixel count field, and indistinctive color pixel count field. Specifically, the hand area ID field is given a specific identifier of a hand area. The state field is given a value of "IN" to indicate entry to a product area. The distinctive color pixel count field is populated with the number of distinctive color pixels counted above, as is the indistinctive color pixel count field with the number of indistinctive color pixels. The hand area data generating unit **222** registers the produced record of hand area data in the hand area data table **215***a*.

(S**16**) The wrist position determination unit **221** receives another picture and its depth data from the sensor device **100**. The wrist position determination unit **221** also receives new skeletal data of the customer seen in the picture.

(S**17**) The wrist position determination unit **221** analyzes the received picture and determines whether the customer's wrist has moved out of the product area. The wrist and elbow positions are obtained in the same way as discussed above for step S**12**.

When the wrist position is found to be out of the product area, the process advances to step S**18**. When the wrist position is still in the product area, the process returns to step S**16**. In other words, the wrist position determination unit **221** repeats steps S**16** and S**17** until it receives a picture in which the customer's wrist is out of the product area.

(S**18**) The hand area data generating unit **222** cuts out an image area surrounding the wrist from the received picture in the same way as discussed above for step S**13**.

(S**19**) Based on the depth of each pixel in the surrounding area, as well as the depth of the of the wrist in question, the hand area data generating unit **222** extracts a hand area in the same way as discussed above for step S**14**.

(S**20**) The hand area data generating unit **222** counts distinctive color pixels and indistinctive color pixels in the extracted hand area, in the same way as discussed above for step S**15**.

The hand area data generating unit **222** then produces a record of hand area data. This record has the same hand area ID as the one produced at step S**15** and contains a value of "OUT" in the state field. The distinctive color pixel count field is populated with the number of distinctive color pixels counted above, as is the indistinctive color pixel count field with the number of indistinctive color pixels. The hand area data generating unit **222** registers the produced record of hand area data in the hand area data table **215***a*.

FIG. **17** is a second part of the flowchart discussed above for an example of how to recognize that a customer is holding a product.

(S**21**) The hand area data comparing unit **223** calculates the ratio of distinctive color pixels in the previous hand area registered at step S**15** to the total number of pixels contained in the same. The hand area data comparing unit **223** also calculates the ratio of distinctive color pixels in the current hand area of step S**20** to the total number of pixels contained in the same. That is, the ratio of distinctive color pixels in each hand area is calculated as a quotient of the number of distinctive color pixels divided by the total number of distinctive color pixels and indistinctive color pixels.

The hand area data comparing unit **223** further calculates a difference between the above two ratios and determines whether the difference is smaller than a predetermined threshold. If the difference is smaller than the threshold, it suggests that the customer seen in the picture has nothing in his or her hands. The hand area data comparing unit **223** thus closes the current process. If the difference is equal to or greater than the threshold, it suggests that the customer seen in the picture has picked up a product. The hand area data comparing unit **223** thus advances the process to step S**22**.

(S**22**) The outputting unit **230** outputs information about the product that the customer has picked up. The product is identified by searching the product data table **211** for a record associated with the product area that the customer's wrist entered and then left. The outputting unit **230** updates a log file by adding, for example, the identifier of the product picked up by the customer, together with a timestamp indicating that moment. Alternatively, the outputting unit **230** may output such product information on a screen of the display **21**. The outputting unit **230** may also output status information indicating the customer's behavior (e.g., compared products or checked information about a particular product).

According to the second embodiment described above, the proposed action recognition system **3** extracts a hand area from each of the pictures taken upon entry of a customer's wrist into a product area and upon exit from the same. The action recognition system **3** then determines whether the customer has picked up a product, based on the ratio of pixels having a distinctive color tone to all pixels in each extracted hand area. The proposed techniques contribute to a better accuracy of determination of such a product-grasping action by a customer.

Specifically, the action recognition system **3** analyzes the depth of each pixel in an image area surrounding a customer's wrist and calculates a depth range based on the depth of the wrist. A hand area is then extracted as a set of pixels whose depths fall in the calculated depth range. The action recognition system **3** further classifies pixels in the extracted hand area into distinctive color pixels and indistinctive color pixels. These features of the second embodiment improve the accuracy of hand area extraction, thus contributing to more accurate determination of whether the customer has picked up a product. While the proposed method includes the task of classifying pixels into two groups, the load of this task is not significant because the task is performed only in a limited hand area. This smallness of hand areas also means an increase in the relative share of distinctive color pixels in a hand area, which further contributes to more accurate determination of a product-grasping action by a customer.

The proposed method relies on the ratio of pixels having a distinctive color tone. This feature makes it possible to recognize a product-grasping action by a customer, regardless of variations in the angle of his or her wrist as it enters or leaves a product area.

The proposed method uses at least two hand area images, one produced upon entry of a customer's wrist into a product area and the other produced upon exit of the same from the product area. The use of these images makes it possible to recognize a product-grasping action accurately even when the indistinctive color pixels occupy a certain percentage of the hand area.

The proposed method further uses the in-picture position of an elbow of a customer, together with that of a wrist, in determining the boundaries of an image area surrounding the wrist. While the wrist angle may vary, and hands may open or close at the customer's will, the noted feature prevents the hand from failing to fit in the surrounding area, thus contributing to more accurate determination of a product-grasping action by a customer.

Whether particular products have been picked up by customers is important information for the shop operator, because picking up a product implies that the customer has felt a certain degree of interest in the product. In other words, it suggests that the customer at least thought of buying the product even though he or she actually did not purchase it. The information helps the shop operator analyze the correlation between such behavior of customers and actual purchase of products, so that the shop operator may be inspired to improve the products per se or the layout of product showcases.

(c) Third Embodiment

This section describes an action recognition system according to a third embodiment. The proposed action recognition system of the third embodiment may be regarded as a modified version of the action recognition system **3** discussed above in the second embodiment. Specifically, the third embodiment is configured to determine the thresholds demarcating a range(s) of distinctive color tone, on the basis of color codes of pixels contained in a hand area. The pixels in the hand area are then classified according to the determined thresholds.

The above features of the third embodiment are expected to work effectively when, for example, the customer wears a pair of globes with a color other than skin colors. If the thresholds are fixed for a particular skin color, then the distinctive color pixel count would be zero in this case, in spite of the fact that the customer's hand is there. The incorrect pixel count would result in a failed determination of whether the customer has picked up a product.

In view of the above issues, the flowchart of FIG. **18** provides an example of how the action recognition system selects more appropriate thresholds on the basis of color code of pixels contained in a hand area each time the wrist position moves into a product area. Since most part of the flowchart of FIG. **18** is similar to the one discussed in the second embodiment, the following description will focus on its difference. See the previous explanation of FIG. **16** in the second embodiment for other features and steps.

FIG. **18** is a flowchart illustrating an exemplary process according to the third embodiment to recognize a customer holding a product. This flowchart differs from that of the second embodiment in its additional step S**14***a* inserted between step S**14** and step S**15**. The flowchart of FIG. **18** assumes that the color code of each pixel is expressed in the RGB format. Step S**14***a* in FIG. **18** performs the following things.

(S**14***a*) The hand area data generating unit **222** selects thresholds for demarcating a range of distinctive color tone, on the basis of color code of pixels contained in the hand area extracted from the picture.

For example, hand area data generating unit **222** calculates an average of pixels in the hand area, for each individual color component (e.g., R, G, B) constituting the color code. The hand area data generating unit **222** then determines the thresholds in reference to the calculated average, so as to establish a certain range of color code for each color component. The hand area data generating unit **222** then applies the calculated thresholds of each color component to steps S**15** and S**20** of classifying pixels in a hand area into distinctive color pixels and indistinctive color pixels.

The calculation of thresholds may be based on statistical data on the color codes of pixels in a hand area, although the above example uses average color components.

According to the third embodiment described above, the proposed action recognition system selects appropriate color thresholds on the basis of color code of pixels contained in a hand area, each time the wrist position moves into a product area. The selected color thresholds are used to distinguish distinctive color pixels. These features of the third embodiment ensure accurate determination of whether a product has been picked up, regardless of what skin color the customers have or what they are wearing on their hands.

As discussed previously, the data processing operations of the first embodiment are implemented as part of functions of an information processing apparatus **2** executing programs encoded therefor. Similarly those of the second embodiment and third embodiment are implemented as part of functions of a sensor device **100** and an action recognition apparatus **200** executing programs encoded therefor. Such programs may be recorded on a non-transitory computer-readable medium (e.g., storage media **23** in FIG. **5**). The computer-readable medium may be, for example, a magnetic storage device, optical disc, magneto-optical storage medium, or semiconductor memory device. Magnetic disk media include, for example, FD and HDD. Optical disc media include CD, CD Recordable (CD-R), CD Rewritable (CD-RW), DVD, DVD-R, and DVD-RW.

Portable storage media may be used for distribution of programs. For example, a computer stores programs in its local storage device (e.g., HDD **203**), which have previously been installed from a portable storage medium or received from another computer. The computer executes programs read out of the local storage device. Where appropriate, the computer may execute program code read out of a portable storage medium, without installing them in its local storage device. It is also noted that the above-described data processing functions may be implemented wholly or partly with a digital signal processor (DSP), ASIC, programmable logic device (PLD), or other electronic circuits, or any combination of them.

Several embodiments and their variations have been described above. In one aspect of those embodiments, the proposed techniques make it possible to accurately determine whether a person seen in pictures has picked up an object.

All examples and conditional language provided herein are intended for the pedagogical purposes of aiding the reader in understanding the invention and the concepts contributed by the inventor to further the art, and are not to be construed as limitations to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although one or more embodiments of the present invention have been described in detail, it should be understood that various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. A method for recognizing actions, comprising:

obtaining, by an information processing apparatus, a picture containing an image of a person from an imaging device, as well as first data indicating distance of the person and other subjects seen in the picture from the imaging device on an individual pixel basis, second data indicating distance of a wrist of the person from the imaging device, and third data indicating a coordinate position of the wrist in the picture;

extracting, by the information processing apparatus, a set of pixels from the obtained picture whose respective coordinates fall within a specified coordinate range defined around the coordinate position of the wrist and whose respective distances fall within a specified distance range defined around the distance of the wrist; and

determining whether the person has picked up an object, based on a ratio representing how many of the extracted pixels have a distinctive color tone.

2. The method according to claim **1**, wherein the extracting pixels and the determining whether the person has picked up an object are performed upon detection of movement of the wrist out of a specified area in a view space.

3. The method according to claim **2**, wherein the method further comprises detecting presence of the wrist in the specified area in the view space, by testing whether the coordinate position of the wrist falls within an area previously defined as part of pictures to be taken by the imaging device.

4. The method according to claim **1**, wherein:

the obtaining a picture, first data, second data, and third data and the extracting pixels are performed at first and second occasions, the first occasion being when the wrist has moved into a specified area in a view space, the second occasion being when the wrist has moved out of the specified area;

the extracting includes extracting first pixels from a first picture obtained on the first occasion, and extracting second pixels from a second picture obtained on the second occasion;

the method further comprises comparing a first ratio representing how many of the first pixels have the distinctive color tone with a second ratio representing how many of the second pixels have the distinctive color tone; and

the determining whether the person has picked up an object is based on a result of the comparing the first ratio with the second ratio.

5. The method according to claim **4**, wherein the method further comprises calculating the distinctive color tone from color code values of the first pixels extracted on the first occasion.

6. The method according to claim **1**, wherein the method further comprises calculating the specified coordinate range from relative positions between the coordinate position of the wrist and another body part located between a shoulder and finger tips of the person.

7. The method according to claim **1**, wherein the distinctive color tone is a range of color code values representing skin colors.

8. An action recognition apparatus comprising:

a processor configured to perform a process including:

obtaining a picture containing an image of a person from an imaging device, as well as first data indicating distance of the person and other subjects seen in the picture from the imaging device on an individual pixel basis, second data indicating distance of a wrist of the person from the imaging device, and third data indicating a coordinate position of the wrist in the picture;

extracting a set of pixels from the obtained picture whose respective coordinates fall within a specified coordinate range defined around the coordinate position of the wrist and whose respective distances fall within a specified distance range defined around the distance of the wrist; and

determining whether the person has picked up an object, based on a ratio representing how many of the extracted pixels have a distinctive color tone.

9. The action recognition apparatus according to claim **8**, wherein:

the extracting pixels is performed upon detection of movement of the wrist out of a specified area in a view space; and

the determining whether the person has picked up an object is performed based on the extracted pixels.

10. The action recognition apparatus according to claim **9**, wherein the process further includes detecting presence of the wrist in the specified area in the view space, by testing whether the coordinate position of the wrist falls within an area previously defined as part of pictures to be taken by the imaging device.

11. The action recognition apparatus according to claim **8**, wherein:

the obtaining a picture, first data, second data, and third data and the extracting pixels are performed at first and second occasions, the first occasion being when the wrist has moved into a specified area in a view space, the second occasion being when the wrist has moved out of the specified area;

the extracting includes extracting first pixels from a first picture obtained on the first occasion, and extracting second pixels from a second picture obtained on the second occasion;

the process further includes comparing a first ratio representing how many of the first pixels have the distinctive color tone with a second ratio representing how many of the second pixels have the distinctive color tone; and

the determining whether the person has picked up an object is based on a result of the comparing the first ratio with the second ratio.

12. The action recognition apparatus according to claim **11**, wherein the process further includes calculating the distinctive color tone from color code values of the first pixels extracted on the first occasion.

13. The action recognition apparatus according to claim **8**, wherein the process further includes calculating the specified coordinate range from relative positions between the coordinate position of the wrist and another body part located between a shoulder and finger tips of the person.

14. The action recognition apparatus according to claim **8**, wherein the distinctive color tone is a range of color code values representing skin colors.

15. A non-transitory computer-readable storage medium storing a program for recognizing actions, wherein the program causes a computer to perform a process comprising:

obtaining a picture containing an image of a person from an imaging device, as well as first data indicating distance of the person and other subjects seen in the picture from the imaging device on an individual pixel basis, second data indicating distance of a wrist of the person from the imaging device, and third data indicating a coordinate position of the wrist in the picture;

extracting a set of pixels from the obtained picture whose respective coordinates fall within a specified coordinate range defined around the coordinate position of the wrist and whose respective distances fall within a specified distance range defined around the distance of the wrist; and

determining whether the person has picked up an object, based on a ratio representing how many of the extracted pixels have a distinctive color tone.

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